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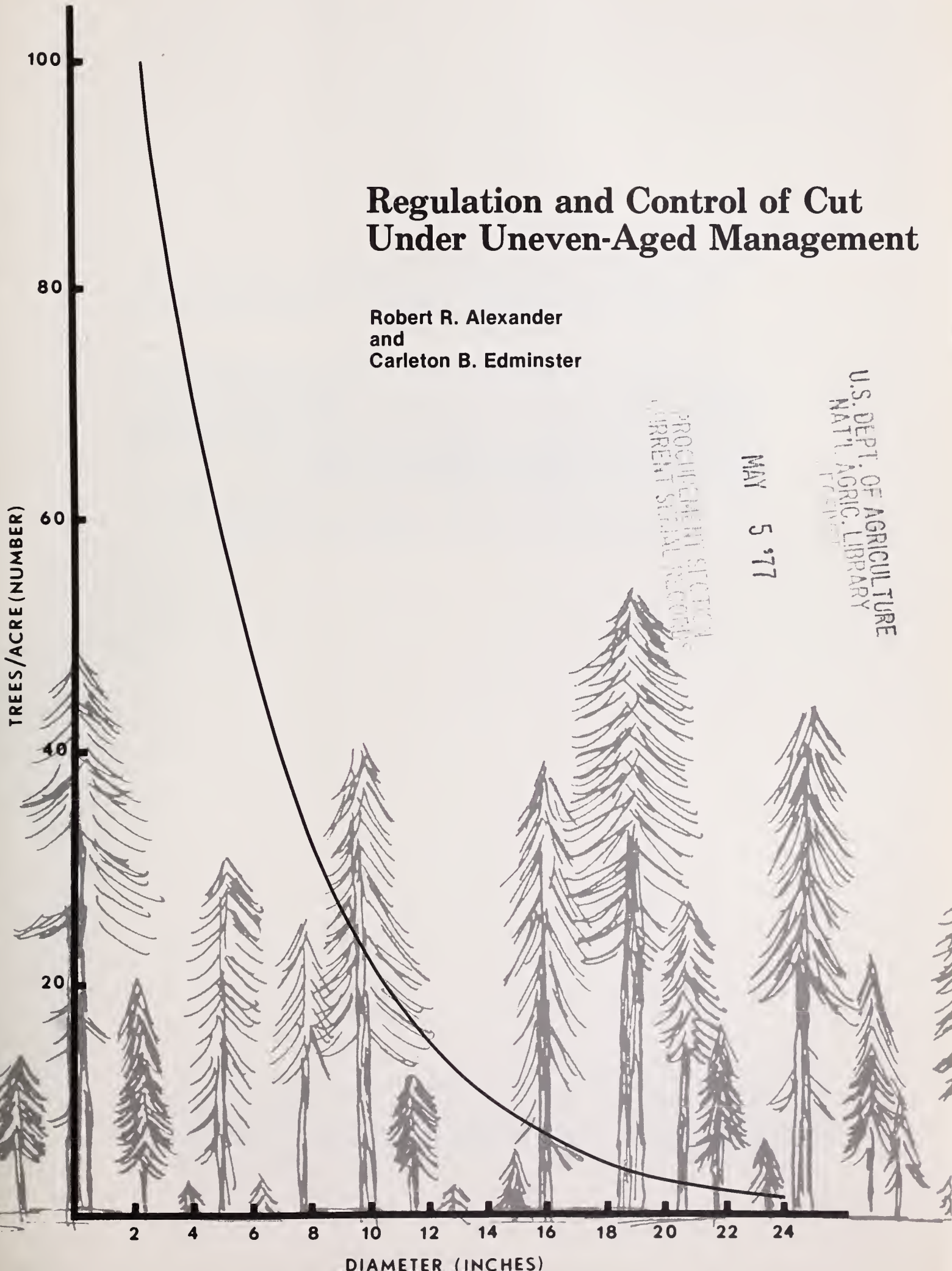


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## Regulation and Control of Cut Under Uneven-Aged Management

Robert R. Alexander  
and  
Carleton B. Edminster



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**Keywords:** Uneven-aged management, regulation, residual stocking.

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**Regulation and Control of Cut  
Under Uneven-Aged Management<sup>1</sup>**

Robert R. Alexander and Carleton B. Edminster<sup>2</sup>

<sup>1</sup>Originally presented at the Western Uneven-Aged Silviculture and Management Workshop. Redding, California, October 19-21, 1976.

<sup>2</sup>Chief Silviculturist and Associate Mensurationist, respectively, Rocky Mountain Forest and Range Experiment Station with central headquarters maintained at Fort Collins, Colorado in cooperation with Colorado State University.

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# Regulation and Control of Cut Under Uneven-Aged Management

Robert R. Alexander and Carleton B. Edminster

## Management Highlights

The objective of regulation of cut is to determine and control the periodic yield of timber products from a specified forest area. The silvicultural systems applicable to uneven-aged management are individual-tree and group-selection cutting. Key elements of regulation of uneven-aged management include setting a residual growing stock goal, a diameter distribution goal, and a maximum tree size goal. The residual stocking level with the best growth varies primarily with species, site productivity, and diameter distribution. Diameter distribution is controlled by establishing the desired number of trees for each diameter class using the quotient  $q$ . Maximum tree size to leave after each cut de-

pends upon site quality, species, management objectives, and other determining factors.

Rotation age is not a valid concept with uneven-aged management because stands are continuously or periodically being regenerated, tended, and harvested, with no real beginning or end. Allowable cut projections with uneven-aged management will include both area and volume control, especially where previously unregulated stands are being brought into a balanced structure. Regardless of projected allowable cut, regulation is subject to supply and demand. Regulation under uneven-aged management will be more expensive than under even-aged management because more frequent stand examinations and more detailed records are required.

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## Introduction

Regulation and control of cut is "the process that deals with the technical aspects of organizing and maintaining a forest property with the objective of determining and controlling the yield of forest products." In this paper we will consider regulation as concerned only with the amount of timber that may be harvested periodically from a specified area over a stated period of time to accomplish management objectives. Since one of the objectives of forest management is to bring previously unregulated stands into a balanced structure, control of growing stock should be emphasized while attempting to keep yield relatively stable during the adjustment period.

In this discussion we are primarily concerned with stands that have irregular structure, are composed of tolerant species, or both. The species most familiar to us that fall into these categories are southwestern ponderosa pine, southwestern mixed conifers, and Engelmann spruce-subalpine fir. Other western species adapted to uneven-aged management are the true firs, hemlock, and interior Douglas-fir—if it has irregular stand structure and is free of dwarf mistletoe.

The silvicultural systems applicable to uneven-aged management are individual tree selection and group selection. Many

silviculturists do not consider group selection a harvesting and regeneration system that meets the constraints of uneven-aged management for sustained yields because there is no realistic procedure for regulating harvest in small groups, and methods have not been developed for determining adequate stocking and acceptable growth of individual trees or groups of trees.

We think uneven-aged regulation can be made to work, with group selection, especially if some of the regulatory unit is under individual-tree selection management. Residual stocking, diameter distribution goals, marking, and growth projection will be the same as for individual-tree selection, but will apply to the regulatory unit rather than individual stands—some groups will be cleaned, others thinned, and still others harvested. Regulation will be difficult, expensive, and require good inventory records and frequent checks on marking.

It is not essential that the uneven-aged forest be defined in a strict silvicultural sense for the purpose of forest regulation. The somewhat arbitrary definition that the uneven-aged forest has no recognizable separate age classes is all that is necessary (Meyer et al. 1961). Even-aged groups may be present, but formal age class regularity of the even-aged forest will not be a goal of management.

## Differences in Regulation Between Even- and Uneven-Aged Management

Uneven-aged management includes the cultural treatments, thinning, and harvesting necessary to maintain continuous high forest cover, provide for regeneration of desirable species either continuously or at each harvest, and provide for the controlled growth and development of trees through the range of size classes needed for a sustained yield of forest products. Managed uneven-aged stands are characterized by trees of many sizes intermingled singly or in groups. Regulation is accomplished by setting (1) a residual growing stock goal in terms of volume (basal area) that must be maintained to provide adequate growth and yield; (2) a stand structure goal in terms of a diameter distribution necessary to provide regeneration, growth, and development of replacement trees; and (3) a maximum tree size goal. Unfortunately, information on growth and yield in relation to stocking, stand structure, and species composition upon which to base growth projections is lacking.

Even-aged management is the cultural treatments, thinning and harvesting necessary for the periodic regeneration of desirable species, the orderly growth and development of trees to a given size in each stand, and the progressive development of stands to provide sustained yield of forest products. Managed even-aged stands are characterized by a distribution of stands of varying age classes throughout the forest. Regulation is accomplished through control of the area in each size or age-class and the length of rotation—the time required to grow trees to some specified measure of maturity. There is a considerable body of growth and yield information. Calculations of projected yields under different management systems are straightforward and reasonably accurate (Myers 1971).

### Regulation of Reserve Growing Stock

Many of the past problems associated with uneven-aged management in the United States resulted from attempts to base regulation on volume control alone. Timber harvests were prescribed on the basis of projections of past growth on the merchantable portion of the stand. Regeneration was left to chance, and the sapling and pole component of the stand received little or no treatment. As a consequence, the high quality stems were cut quickly, long-term yields were reduced, and stand vigor declined.

In managed or unregulated stands being brought under management, a procedure must be established so that stands can be periodically cut back to some desired residual structure with some degree of accuracy. The difference between the volume (by diameter classes) of the existing stand and volume of the specified residual stand is **current yield**. Finally, growth must be projected for at least one cutting cycle to determine expected future yield. The problem is to decide what kind of trees, and how many, are to be cut on what schedule to obtain the balanced stand needed to provide sustained yields.

Total stand growth for many species adapted to uneven-aged management doesn't differ greatly over the range of stocking levels likely to be management goals. Consequently, stocking levels set near the lower limit where no stand growth is lost concentrates increment on the fewest number of stems. This reduces the time required to grow individual trees to specified size, and represents a minimum investment in growing stock.

The residual stocking level with the best growth varies primarily with species, productivity, and diameter distribution. The only stocking standard we could find for Rocky Mountain species was developed by Bert Lexen for southwestern ponderosa pine as follows:

D.b.h. class	Trees per acre	Basal area per acre
<i>In</i>	<i>No.</i>	<i>Ft<sup>2</sup></i>
2	105.4	2.29
4	71.0	6.20
6	48.0	9.50
8	32.4	11.31
10	21.8	11.89
12	14.8	11.62
14	10.0	10.69
16	6.8	9.49
18	4.5	7.99
20	3.1	6.72
22	2.1	5.44
24	1.4	4.40
Total	322.4	97.55

From his studies of space requirements of ponderosa pine of different diameters, he recommended a residual basal area of 98 ft<sup>2</sup> for a range of site indexes from 75 to 100. Although Lexen's growing-stock table was developed from actual data in existing stands, it is essentially 57 percent of normal stocking for all-aged stands synthesized from normal yield tables for even-aged stands (W.H. Meyer 1961). C. A. Myers adopted Lexen's standard as one stocking goal for a study of yield of individual-tree selection forests of southwestern ponderosa pine, and obtained

another by proportion. G. H. Schubert adapted Lexen's standard to a range of basal areas from 20 to 180 ft<sup>2</sup>.

In unregulated old-growth spruce-fir stands with irregular structure, stocking usually ranges from 150 to 300 ft<sup>2</sup> of basal area per acre. This probably represents something close to full to overstocking. While no guidelines are available for uneven-aged stands, residual stocking goals of GSL-80 to GSL-120 are suggested for managed even-aged spruce-fir, depending on site productivity, number of entries, and other management objectives (Alexander et al. 1975). These levels in terms of ft<sup>2</sup> of basal area per acre should be useful in estimating initial stocking goals for that part of the stand that will eventually be regulated under uneven-aged management.

The use of yield tables for even-aged stands in setting stocking goals for uneven-aged forests may not be appropriate for all species. This method assumes that there is little difference between the growing stock of even-aged and uneven-aged forests, other than a redistribution of age classes over a smaller area (Bond 1952). This pattern may well develop when stands of intolerant to moderately tolerant species are harvested by a group-selection method. The end result may well be a series of small even-aged groups represented in the same proportion as the series of age classes in even-aged management. If more shade-tolerant species are harvested by a group- or individual-tree selection method, however, a different pattern may develop. Often, advanced growth of smaller trees will become established under a canopy of larger trees. Growing space occupied by each age or size class is being shared (Reynolds 1954). Assuming that logging damage to the understory trees can be controlled, advance growth will successfully establish a series of age classes on at least some acres. In this situation, more trees of larger size can be grown per acre than is possible with a balanced even-aged growing stock (Bourne 1951, H. A. Meyer et al. 1961). The use of yield table data for such stands can predict inaccurate results (Walker 1956).

As pointed out earlier, control over the diameter distribution is also necessary to regulate yields under uneven-aged management. This, the most important step, is accomplished by establishing the desired number of trees for each diameter class.

To allow for continuous yields, the curve of number of trees plotted over diameter class should have roughly an inverse J-shape. There are a number of ways to express, measure, or calculate diameter distributions. The quotient  $q$  between number of trees in successive 1- or 2-in diameter classes is an accepted method (H.A.

Meyer 1952). Quotients ranging between 1.3 and 2.0 (for 2-in classes) have been recommended for various situations. The lower the  $q$ , the smaller the difference in number of trees between diameter classes. Stands maintained at a small  $q$  have a higher proportion of available growing space in larger trees.

Lexen did not use  $q$  to establish diameter distribution for ponderosa pine in the Southwest, but when his residual numbers of trees per acre are plotted over diameter classes, the resulting curve is a typical inverse J-shape (fig. 1). The  $q$  value for the distribution approximates 1.5.

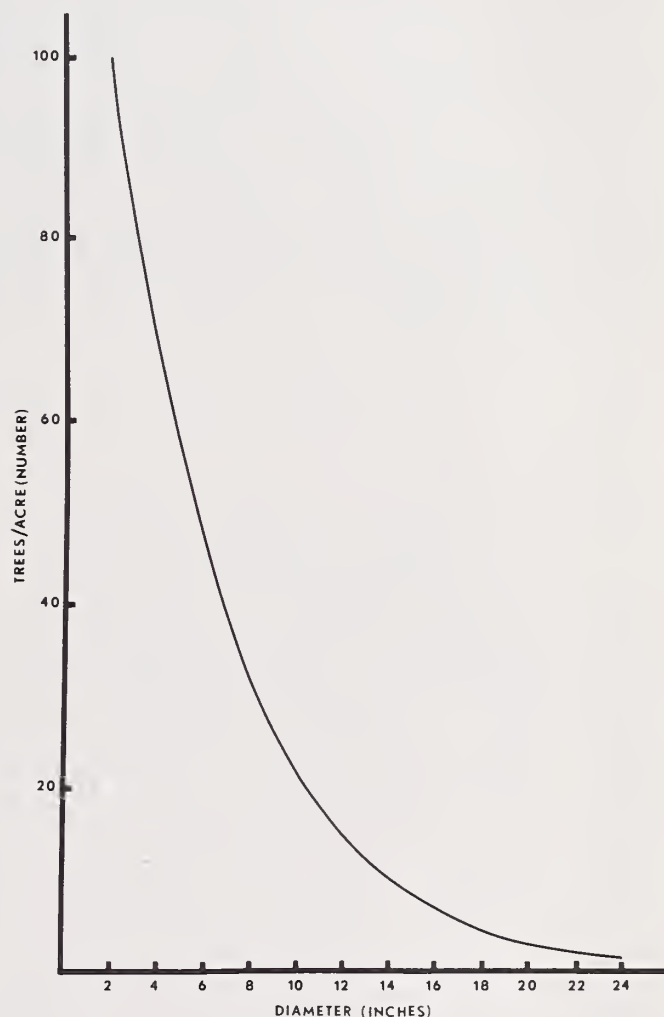


Figure 1.—Lexen's stocking curve for uneven-aged stands of southwestern ponderosa pine.

In irregular spruce-fir stands, the diameter distribution from plot data provide the basic information needed to obtain an actual stocking curve. In the absence of any experience data or good growth and yield information, some arbitrary  $q$  level (1.5, for example) could be used to calculate the number of trees by diameter classes and obtain basal area. This basal area can be adjusted by proportion to obtain the number of trees in each diameter class to meet desired residual basal area (Trimble and Smith 1976).

Comparing curves of the actual and desired diameter distributions will show where deficits and surpluses occur (figs. 2 and 3). To bring a stand under regulation, management should be concerned with increasing the number of trees where needed along the residual stocking curve, and cutting within the range of surplus trees. As a guiding policy, enough trees should be left above the curve in the surplus diameter classes to balance the deficits in diameter classes below the curve.

The need for developing diameter distributions for trees in the unmerchantable diameter classes is questionable. In the Rocky Mountains, minimum merchantable diameters are 5 to 8 in for most species. Trees below these sizes would be unregulated, but they should not be ignored in recordkeeping. These trees may compete for growing space with larger stems, and we need to know what is happening. More importantly, however, they provide the ingrowth into the merchantable size classes needed for individual tree selection. Since these trees are likely

to be unregulated, cutting may be heavy in the threshold size classes to obtain the desired numbers of trees in the regulated part of the stand.

It is not likely that unregulated stands will be brought under control with one cut or even a series of cuts. More likely, limitations imposed by stand conditions, windfall, and insect and disease susceptibility will result in over- or undercutting. Yields from harvest will fluctuate until some balanced diameter distribution is obtained. Even under regulation, it is not possible or necessary to obtain a theoretical diameter distribution on every acre. Furthermore, when it comes time to mark stands for cutting, diameter classes broader than 1 or 2 in may be used (H. A. Meyer 1943).

Stand structure goals to regulate uneven-aged stands are primarily to provide a balanced diameter distribution that will support periodic yields of about equal volumes. Growth and yield determination may have to be based on intertree competition, independent of structure.

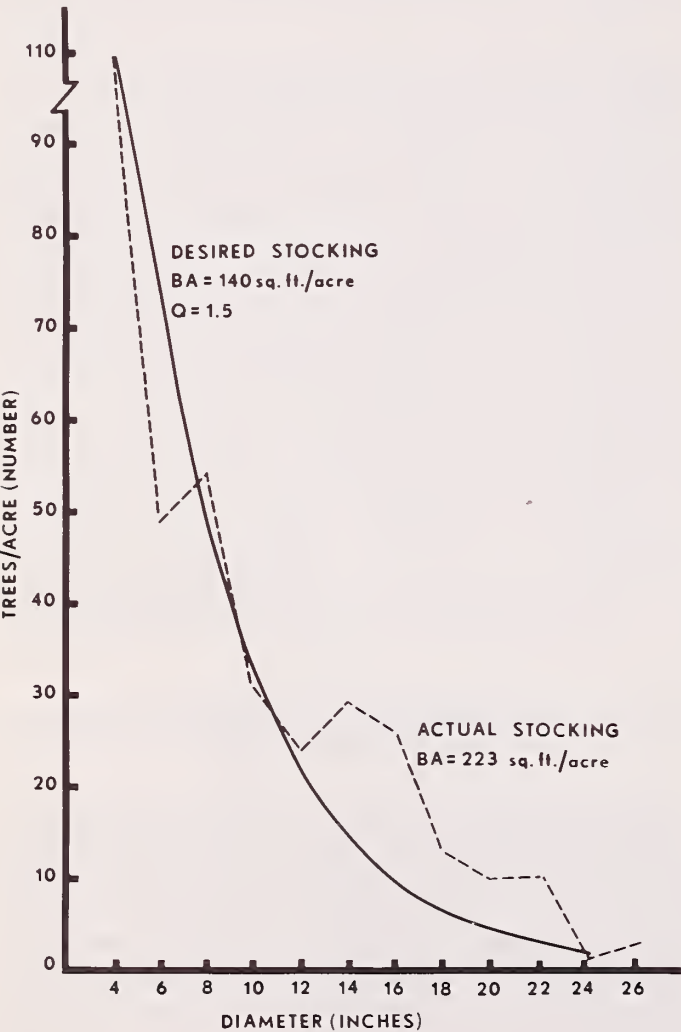


Figure 2.—Comparison of actual and desired ( $q = 1.5$ ) stocking curves for a spruce-fir stand.

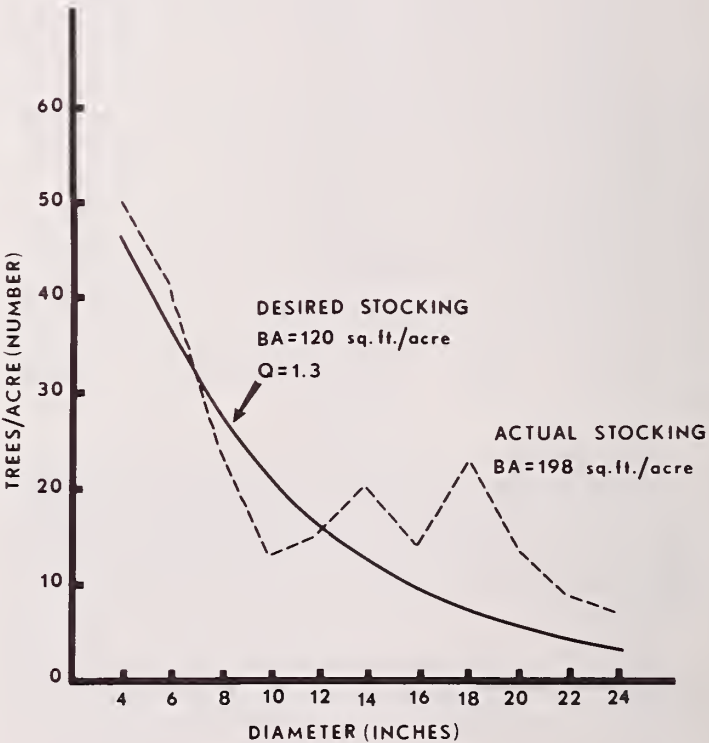


Figure 3.—Comparison of actual and desired ( $q = 1.3$ ) stocking curves for a spruce-fir stand.

The maximum tree size to leave after each cut depends upon site quality, species, management objectives, and other factors. Without any readily apparent reason, Lexen selected a maximum diameter of 24 in at breast height. Examination of yield table predictions for even-aged spruce stands, and plot inventory information from unmanaged stands with irregular structure, suggests a diameter of 24 in can be attained within a reasonable time for a wide range of stocking and site quality. In the absence of any information on growth rates, or rate of return for specific diameter and stocking classes, this seems to be a reasonable first approximation to set for timber production. Trees of larger diameter with a lower rate of return on investment may be appropriate for multiple-use reasons.

Prescribing residual volumes, diameter distributions, or tree size goals that cannot be applied or attained is an exercise in futility. Regulation of uneven-aged forests fails unless the prescribed structure can be marked in the field with some degree of accuracy. Marking in stands of a species mixture such as spruce-fir, for example, is difficult because of limited inventory information. The marker must designate cut or leave trees adequately with one pass through the stand. At the same time, he must apply good silviculture and be aware of economic limitations. As a general rule, good silvicultural prescriptions are more important than strict adherence to structural goals, especially in unregulated stands being cut for the first time. However, marking without a structural goal defeats the objective of regulation.

Marking for individual tree selection is more complex than for other systems, and some formal control procedure is usually necessary. Often only an estimate of the initial stand and the desired residual diameter distribution is needed. With these estimates, basal area and number of trees to be removed by diameter class can be determined. Control is maintained by process of successive checks and revisions toward the desired stand structure.

#### **Rotation Age — A Valid Concept With Uneven-Aged Management?**

Under a system of even-aged management, the rotation age is the number of years required to establish and grow a stand of trees to some specified measure of maturity. Economic, pathological, technical, and silvicultural considerations should enter into setting the rotation age. Even-aged stands are regenerated, tended, and harvested during the specified rotation, and the sequence is then repeated. Stand development is a function of tree age. The rotation age is a key

component in regulating the cut, since the harvest is determined in relation to it.

With uneven-aged management, stands are continuously or periodically being regenerated, tended, and harvested, with no real beginning or end. The silviculturist needs to know the amount of time required to produce a tree of a certain size, under given stand conditions, but the cut is not based on tree ages. No separate age classes are recognized, and the actual age of a tree or group of trees is of little practical importance. Volume per acre cannot be expressed as a function of average tree age, and the rotation age is not a valid basis for regulation. Regulation of the cut is determined in relation to growing-stock level and distribution, the cutting cycle, and the rate of volume and value growth. The size and condition of a tree and its capacity to grow are much more significant than its actual age.

What is essential in a regulated uneven-aged forest is that all sizes of trees be represented in balanced proportion, and that these trees be able to reach their growth potential (H.A. Meyer 1943). The inadequacy of regulation based on fixed rotations applied to the management of irregular and uneven-aged forests has been discussed by Kirkland (1925, 1934).

#### **Cutting Cycles in Uneven-Aged Management**

The interval between cuts will vary with the rate of growth, residual stocking level, site quality, volume available for cutting, accessibility, economic constraints, and intensity of management. In western coniferous forests, cutting cycles under even-aged management vary from 10 to 40 years. From a silvicultural point of view, cutting should be timed to coincide with the return of the residual stand to full stocking—that point where growth begins to diminish. In actual practice, re-entry schedules are usually set at multiples of 10 years for convenience of record-keeping. In unregulated coniferous stands that are being brought under management, where specific growth information is lacking, a cutting cycle of 20 to 30 years seems reasonable. In stands with incomplete representation of diameter classes, volumes available for cutting may not warrant this frequency of re-entry until a controlled diameter distribution is attained.

Intensity of silviculture and the relation of the growth rate to economic constraints are probably the most important factors in choosing the length of the cutting cycle. With intensive management and rapid growth, the growing stock distribution can be changed more rapidly with a short cycle. Frequent cuttings allow natural

mortality to be reduced by removing high-risk trees. With a short cycle, relatively small volumes are removed per acre in a single cut that leaves a large growing stock for the next cut. Displacement of actual growing stock from growing stock distribution goals is relatively small.

Longer cutting cycles under more extensive management require that considerable volumes be removed per acre in a single cut. Displacement of actual growing stock from desired goals may be significant, leaving a smaller residual growing stock to put on less volume growth than a denser residual stand. With longer cycles, mortality may also affect the estimate of net volume growth.

Cutting cycles are usually established for a compartment, but larger or smaller subdivisions may be used. Trees can be cut every year in some part of the management unit, or at periodic intervals. Regardless of the intervals of re-entry, each stand should be examined before treatment to determine what needs to be done and when it should be accomplished. After treatment, another examination is required to determine what was accomplished in terms of goals set.

### Allowable Cut Projections

Under uneven-aged management with individual tree selection, allowable cut projections are relatively simple and straightforward, in concept, and easy to accomplish, at least for one cutting cycle. Attempts to project yields through many cutting cycles with present growth and inventory data are not realistic. The number of trees and basal area by diameter classes are obtained from the past logging inventory. Expected growth increases and the number of trees by diameter classes are projected to predict the stand at the time of the next cut. The difference between the specified residual (present) stand structure and the projected (future) stand structure is the allowable cut. Allowable harvest for the regulatory unit would be obtained by following this procedure for each stand or compartment and summing the expected yields. Irregularities in year-to-year yields can be smoothed out to some extent by adjusting the time individual stands are cut.

The difficulty with this procedure is lack of growth data for even short-term projections. Ideally these projections would be made from measurement data on growth plots in each

regulatory unit. Unfortunately, these kinds of re-measurement data are hard to come by, and published information on growth in uneven-aged stands of western coniferous species is almost nonexistent. Furthermore, data obtained from present forest inventory procedures may not be suitable for growth projections. The major obstacle to growth projections is, of course, lack of long-term yield estimates for managed stands comparable to that available for even-aged stands.

Two general approaches to determination of the allowable cut have long been recognized: area control and volume control. A certain amount of confusion has resulted from this division. Usually, area control is most appropriate for even-aged forests and volume control for uneven-aged forests (Bond 1952). In practice, however, regulation of the cut and development of a cutting plan include both volume and area regulation (Guilkey and Gevorkiantz 1949, Meyer et al. 1961). They may, therefore, be used to complement each other in determining the level of cut and the cutting plan.

### Markets and Financial Aspects of Regulation

Regardless of the projected allowable cut, regulation is subject to supply and demand. We cannot increase the volume of timber sold above what the market can take. We can only limit the amount sold. Furthermore, timber sold may not be cut on schedule. Since uneven-aged management requires cutting in all classes, markets must be developed for small-diameter trees. Otherwise the cost of removing this material will have to be carried by the merchantable portion of the stand.

Regulation under uneven-aged management is more expensive than under even-aged management. Stand examinations to update inventory and growth information must be made at more frequent intervals. More detailed records of average volumes, size classes, cutting schedules, and other pertinent data, are required for control of the cut. Marking trees to be removed is more complex and time consuming. A complete, permanent road system and skid trail location and layout that will permit frequent entries into the stand with minimum damage to the residual are also needed for successful regulation.

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